Wind profile above the surface boundary layer

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There is growing interest in predictions of the wind profile in the lowest hundreds meters of the atmosphere, being connected to the general increase in height of structures such as bridges, high houses and wind turbines. The hub height of modern wind turbines extends presently above the surface layer the majority of the time. Long range transport of air pollutants are controlled by the wind profile in the whole boundary layer and not only near the ground.

Meteorological measurements at the National Test Site for Wind turbines at Høvsøre (Denmark) and at a TV tower south-east of downtown Hamburg (Germany) shows that the neutral wind profile in the boundary layer becomes non-logarithmic with increasing height. Straightforward application of the conventional and generally accepted wind profiles by Businger predicts well the wind profile in the surface boundary layer, but is found to perform poorly above ≈50 meters height in both unstable, neutral and stable conditions.

An extension of the conventional wind profile is formulated for the entire boundary layer. The friction velocity is taken to decrease linearly through the boundary layer. The length scale is composed of three terms, near the ground the length scale is taken to increase linear with height with stability correction following Monin-Obukhov similarity, above the surface boundary layer the length scale is not proportional to height any more but becomes near constant. At the top of the boundary layer the length scale is assumed to be negligible. A simple model for the length scale that controls the wind profile and its stability dependence is formulated by inverse summation.

Proper connection between the friction velocity near the ground and the geostrophic wind velocity is secured by application of the geostrophic drag law. In this way the wind profile for the entire boundary layer can be integrated and is found to depend on three non-dimensional numbers, a dimensionless surface roughness (surface Rossby number) $u_*/f\,z_0$,a dimensionless stability number formulated in terms of the Monin-Obukhov length (Monin-Kasanski number) $u_*/f\,L_{MO}$ and a new number that represents the length scale (L_{MBL}) in the middle of the boundary layer $u_*/f\,L_{MBL}$.